



IMPROVING COMMUNICATION FOR PEOPLE WITH HEARING LOSS

CONFERENCE PROCEEDINGS

March 14-15, 2017
Stanford University



The Stanford Center on Longevity gratefully acknowledges the support of Katherine and David deWilde for generously underwriting the conference.

Table of Contents

Conference Participants.....	2
Conference Agenda.....	5
Introduction: Improving Communication for People with Hearing Loss.....	7
Overview of Hearing Loss: What Do We Know and What Needs to Be Done?.....	9
Session I: How Acoustics and the Built Environment of Public and Private Spaces Can Support Better Communication.....	12
Imagining Possibilities: The Meyer Sound Constellation System.....	15
The Future of “Hearability”: Where Could We Go From Here?.....	16
Session II: Integration and Inter-operability of Technology and Services.....	20
Session III: How Policies, Research, and Education Can Influence Change.....	24
Session IV: Setting the Research Agenda.....	26
Conclusions.....	29
Resources.....	30
Endnotes.....	31

Conference Participants

Gretchen Addi

Consultant and Designer-in-Residence, AGING2.0

Jennifer Alyono

Fellow, Otolaryngology/Neurotology, Stanford University School of Medicine

Amy Andonian

President and Chief Executive Officer, Avenidas

Stavros Basseas

Co-founder and Principal, SoundWorld Solutions

Brenda Battat

Former Executive Director, Hearing Loss Association of America

Barbara Beskind

Tech Designer, IDEO

Cindy Beyer

Vice President, HearUSA

Nikolas Blevins

Professor of Otolaryngology and Professor of Neurosurgery, Stanford University School of Medicine

Rika Bosmans

Managing Director, Stanford Center on Longevity

Laura Carstensen

Professor of Psychology, Stanford University; Director, Stanford Center on Longevity

Chris Chafe

Professor of Music, Stanford University; Director, Center for Computer Research in Music and Acoustics (CCRMA)

Herbert Clark

Professor of Psychology, Emeritus, Stanford University

Robin Cole

Accommodations Coordinator, Office of Accessible Education, Stanford University

Marie Conley

Social Sciences Research Professional, Stanford Center on Longevity

Poppy Crum

Chief Scientist, Dolby Laboratories and Consulting Professor, Stanford University

Mark Cullen

Professor of Medicine, of Biomedical Data Science, of Health Research and Policy, Stanford University School of Medicine; Senior Fellow, Stanford Institute for Economic Policy Research (SIEPR)

David deWilde

Private investor; Member, Advisory Council, Stanford Center on Longevity

Doron Dorfman

Graduate Student, Stanford School of Law

Judy R. Dubno

Professor, Director of the Hearing Research Program, Medical University of South Carolina

Thibault Duchemin

Chief Executive Officer and Founder, Ava

Laura Dunn

Professor of Psychiatry and Behavioral Sciences, Stanford University School of Medicine

David Eagleman

Neuroscientist, Department of Psychiatry and Behavioral Sciences, Stanford University School of Medicine

Nancy Easterbrook

Director of External Affairs, Stanford Center on Longevity

Matthew Fitzgerald

Assistant Professor of Otolaryngology/Head and Neck Surgery, Chief of Audiology, Stanford University School of Medicine

Amanda French

Graduate Student, Stanford University, Bioengineering

Pierre Germain

Constellation Design Manager, Meyer Sound

Justin Golub

Assistant Professor, Otolaryngology-Head and Neck Surgery, Columbia University Medical Center

Cynthia Hutchins

Director of Financial Gerontology, Bank of America/Merrill Lynch

Robert Jackler

Professor in Otorhinolaryngology and Professor, by courtesy, of Neurosurgery and of Surgery, Stanford University School of Medicine

Zina Jawadi

Undergraduate Student, Stanford University, Department of Biology

Jim Johnson

Chairman and Chief Executive Officer, Johnson Capital Partners

Laura Lee

Undergraduate Student, Stanford University, Departments of Psychology and Management Science and Engineering

Frank Lin

Professor of Otolaryngology, Geriatric Medicine, Mental Health, and Epidemiology, Johns Hopkins University

Kristen Liu

Director, Accessibility & Advocacy, Doppler Labs

Lawal Luqman

Director, Global Health and Research, Starkey Hearing Foundation

Hope Mitnick

Architect and Founding Principal, Odessa Architecture

Sheri Peifer

Chief Strategy Officer, Eskaton

Gerald Popelka

Consulting Professor of Otolaryngology/Head and Neck Surgery, former Chief of Audiology, Stanford University School of Medicine

Jack Rowe

Professor, Department of Health Policy and Management, Columbia University Mailman School of Public Health

Charles Salter

Acoustical Engineer, President of Charles M. Salter and Associates, Inc.

Sheila Sanchez

Associate Director and ADA Program Director, Diversity and Access Office, Stanford University

Daniel Shen

Founder, Chief Clinical and Science Officer, Eargo

Bob Smith

Director, Classroom Innovation, Stanford University

Susi Stadler

Principal at Stadler Architecture; Cofounder and Executive Director, At Home With Growing Older

Jonathan Streeter

Social Sciences Research Professional, Stanford Center on Longevity

Austin Swanson

Lead Audiologist, Stanford Hospital

Tobi Szuts

Research Scientist, Meyer Sound

Lily Truong

Cofounder and Chief Executive Officer, Clear Ear

Yona Vaisbuch

Clinical Instructor, Otolaryngology, Stanford School of Medicine

Anthony Wagner

Professor of Psychology, Stanford University

Amy Yotopoulos

Director, Mind Division, Stanford Center on Longevity

Conference Agenda

Day 1: Tuesday, March 14, 2017

2:30 – 3:00 p.m.	Registration opens
3:00– 3:30 p.m.	Welcome, Introductions, and Conference Goals Jim Johnson Laura Carstensen Gerald Popelka
3:30 – 3:45 p.m.	Opening Presentation by Frank Lin “Overview of Hearing Loss: What Do We Know and What Needs To Be Done?”
3:45 – 4:30 p.m.	Session I: How Acoustics and Built Environment of Public and Private Spaces Support Better Communication Moderated by Brenda Battat
4:30 – 4:40 p.m.	Walk to Lathrop Room #282 A classroom with the Meyer Sound Constellation system installed
4:40 – 5:30 p.m.	Tour and Continued Discussion of Acoustics and Built Environment at Lathrop #282 Moderated by Bob Smith
5:30 – 5:40 p.m.	Return to GSB Common Room
5:40 – 6:15 p.m.	Happy Hour in Courtyard
6:15 – 8:00 p.m.	Dinner with Panel Discussion
7:00 p.m.	The Future of “Hearability”: Where Could We Go From Here? Moderated by Mark Cullen Panelists: Robert Jackler Gretchen Addi Amanda French David Eagleman
8:15 p.m	Adjourn

Day 2: Wednesday, March 15, 2017

7:30 a.m.	Shuttle from Sheraton Hotel to GSB Common Room
7:45 – 8:15 a.m.	Breakfast
8:15 – 10:00 a.m.	Session 2: Integration and Interoperability of Technology and Services Moderated by Zina Jawadi
10:00 – 11:30 a.m.	Session 3: How Policies, Research, and Education Can Influence Change Moderated by Jack Rowe
11:30 – 11:45 a.m.	Break
11:45 – 12:30 p.m.	Session 4: Setting the Research Agenda Moderated by Laura Carstensen
12:30 p.m.	Lunch and Adjourn

Introduction: Improving Communication for People with Hearing Loss

A Growing and Urgent Problem

One out of every five Americans – roughly 48 million people – suffer from significant hearing loss,¹ and the number is expected to nearly double by the year 2030. The prevalence of chronic hearing loss rises steeply with age, from 30 percent among adults 45 to 60 years of age, to 40 percent among adults aged 65 to 74, and 56 percent among adults who are 75 and older.² This makes hearing loss the third most prevalent chronic medical condition among older adults, following arthritis and hypertension.³ Hearing impairment is associated with social isolation, depression, risk of dementia, higher risk of falls, and early mortality.

A Majority of Americans with Hearing Loss Do Not Get Treatment, At Risk

Some 95 percent of cases are permanent and irreversible, but can be treated effectively with a variety of hearing devices such as hearing aids. Still, 80 percent of those who could benefit from a hearing aid do not wear one,⁴ often due to the stigma associated with hearing loss or the high costs of hearing aids. For those who do seek treatment, the average time between initial diagnosis and commencement of use of a hearing aid is seven to 10 years.⁵ Untreated hearing loss is associated with concurrent disorders including reduced communication ability, functional and psychosocial impairments,⁶ cognitive decline,⁷ and physical disability.⁸

Hearing Loss and Social Engagement

Hearing loss tends to impair communication, an important source of human intimacy, and there is some evidence that it can lead to social isolation and loneliness – both of which are also risk factors for mortality. Just as some studies reported significant associations between hearing status and loneliness,^{9, 10, 11, 12} others found none.^{13, 14, 15} There is also some evidence that treatment with hearing aids and other devices, in combination with improving environmental factors such as ambient noise, can mitigate loneliness.¹⁶

Impact on Work and School

In addition to hearing aids and other personal listening devices, the acoustics of various environments strongly influence the ability to hear: a poor acoustic environment is as much a barrier for people with hearing loss as a staircase is for people in wheelchairs.¹⁷ In the workplace, those with untreated hearing loss have lower earnings.¹⁸ At school, a child with even mild hearing loss can miss as much as 50 percent of classroom discussion.¹⁹

The Plan

In 2017, the Stanford Center on Longevity launched a research program examining key unanswered questions about hearing loss and social engagement. The aim of the project is to identify areas for future research: currently, only limited research has probed the impact of hearing loss, whether treated with devices or not, and its related effects on social engagement.

We convened a group of distinguished experts on March 14 and 15, 2017, representing the fields of medicine, engineering, psychology, sociology, law, government, health economics, health policy, industry, technology, and advocacy, to elaborate key issues, compile existing evidence, and identify questions to which answers are needed in order to guide research, inform public policy, and improve products and services.

The Hearing Project at the Stanford Center on Longevity will include developing research and policy programs to address the following issues:

Access, Prevention, and Education:

- Improve access to hearing aids and other hearing devices in the general population. Develop ways to simplify and clarify the pathways to obtaining this technology.
- Better understand the reasons why people with access do not use hearing devices. Discover which interventions can help remove the barriers to and increase the use of hearing devices.
- Research the best ways to educate the population on the prevention of hearing loss, as well as the effects of untreated hearing loss. Understand the most effective ways to educate users on all the technical features of hearing aids, and how they can interact with other devices.

Technology:

- Develop new technologies to accommodate diverse situations, and determine which current technologies are underutilized in service to the hearing impaired.

Policies:

- Better understand the policies that might allow for greater access to hearing aids and other hearing devices.
- Support policies for improving the integration of assisted listening devices in public spaces.

Acoustics and Built Environments:

- Discover and maximize acoustic environments for conversation and social engagement, especially in public places.
- Encourage architects, developers, and builders to incorporate technology specifically designed to decrease acoustic barriers in their site planning, architectural design, materials selection, and construction methods.

The results of this project will provide actionable insights into the usage, technology, and policies related to greater adoption of hearing aids and other hearing devices, as well as related methods for acoustically improving built environments. Further, the results of this project will provide insights into the effects of hearing devices and improved acoustics on communication among individuals with varying degrees of hearing loss. Data and resources collected by the Hearing Project may serve as a starting point for future research. Ultimately, the Hearing Project seeks to improve overall the psychological, physical, and cognitive well-being of the hearing-impaired and those who interact with them.

Following the meeting, the project will seed pilot research on identified topics and convene practitioners, patients, and other stakeholders to develop a strategic plan to improve communication for those with hearing loss in America.

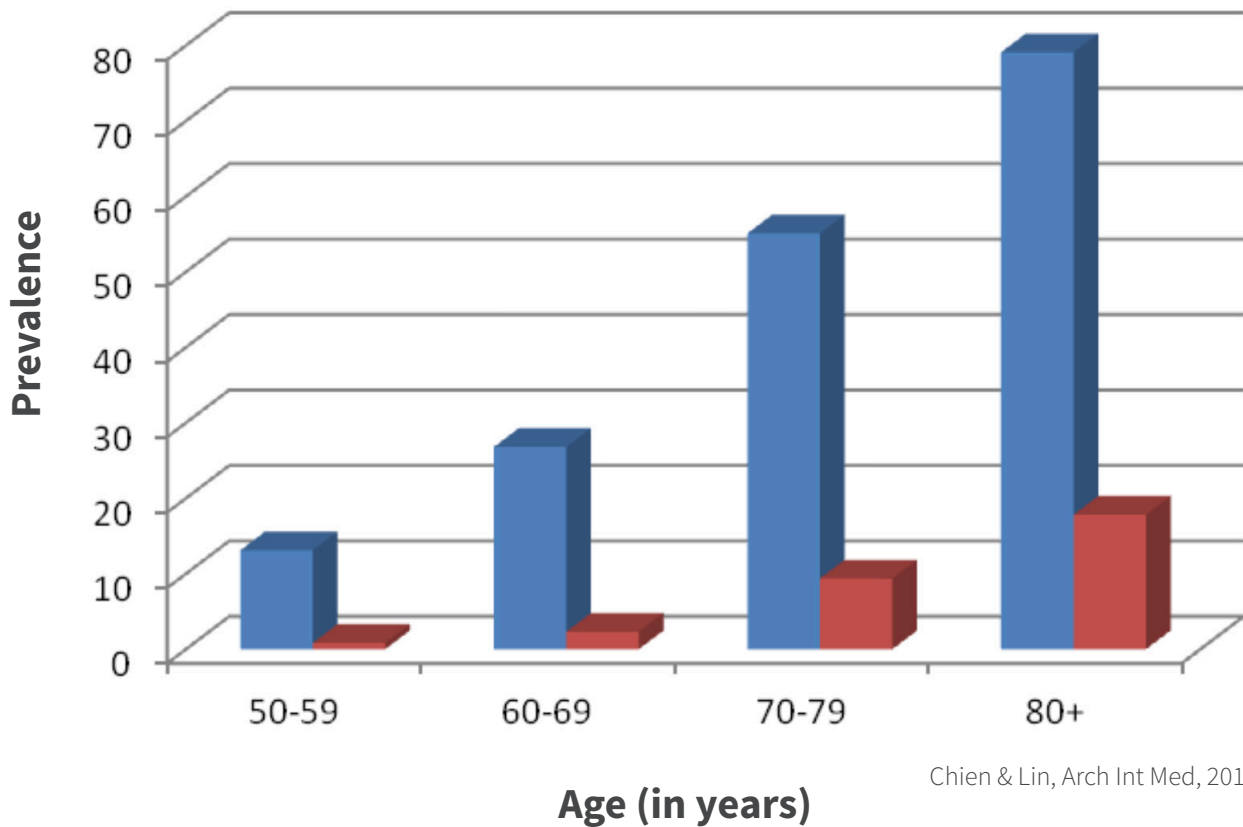
Overview of Hearing Loss: What Do We Know and What Needs to Be Done?

Frank Lin, Associate Professor of Otolaryngology, Geriatric Medicine, Mental Health, and Epidemiology at Johns Hopkins University

The prevalence of hearing loss in the United States doubles with every decade of age, resulting in two out of three people over the age of 70 experiencing some level of hearing impairment, yet only 15 to 20 percent of the hearing impaired use hearing devices – a figure that has not changed in three decades, said Frank Lin, Associate Professor of Otolaryngology, Geriatric Medicine, Mental Health, and Epidemiology at Johns Hopkins University.

Hearing Loss and Hearing Aid Use

Prevalence in the U.S., 1999-2006



What are the consequences?

Hearing loss is strongly linked to other negative health outcomes, including reductions in cognitive functioning and social engagement, brain atrophy, and risk of disability.

What is the impact of treating hearing loss?

Despite the anecdotal effects reported by individuals who have received hearing loss treatment, the broader health and societal impact of treating hearing loss is unknown: to date, no randomized control trials have explored this question. Although a definitive, randomized, trial of the impact of hearing loss treatment is currently being led by investigators at Johns Hopkins, the final results of this trial won't be available until 2023. A recent commissioned report by the Lancet concluded that hearing loss, among all potentially modifiable dementia risk factors, accounts for the greatest proportion of dementia risk.

How do we address the fact that 60 percent of adults are afflicted with age-related hearing loss (ARHL)?

There are three federal policies in place that affect treatment of hearing loss:

1. Since its inception, Medicare has excluded coverage of hearing aids as well as reimbursements to audiologists for counseling and education. (U.S. Social Security Administration, 1965)
2. By statute, hearing aids can only be sold by licensed professionals and not purchased over-the-counter.
3. ADA section 219 requires accommodation of hearing loss through assistive listening systems. (U.S. Department of Justice, 2010)

What are the barriers to hearing assistance and care?

- Awareness: There is an ongoing lack of awareness and understanding of hearing devices and their potential for mitigating an individual's hearing loss.
- Access: The consumer's ability to obtain services as well as hearing technologies is problematic: patients are required to go back and forth to an audiologist or another hearing care provider.
- Cost: Though the high cost of hearing aids is a significant factor, cost is not the sole issue as there is only marginally higher use of hearing aids in countries that cover the cost of hearing care through insurance.
- Technology design: Current technologies have often not been directly designed with the end-user in mind, but rather to be sold and managed by a hearing professional.

Solutions:

- View hearing loss in the context of public health. (White House Conference on Aging)
- FDA re-classification of hearing devices, to allow for over the counter (OTC) devices. The Over-the-Counter Hearing Aid Act of 2017 was recently passed into law in August 2017, and this law mandates that the FDA re-regulate hearing aids by 2020 to allow for over-the-counter sales. This re-regulation is widely anticipated to lead to an influx of new technologies for hearing loss that will be developed by both the established hearing industry as well as consumer electronic companies.
- Introduce bipartisan legislation calling for insurance companies to cover audiological rehabilitative services and hearing devices.
- Itemize the cost of hearing devices separately from the cost of audiological services to allow for greater transparency to consumers.

Other issues:

- Blurring of the line between “medical device” and “consumer electronics.”
- Doctors and audiologists oppose the introduction of over-the-counter hearing devices, claiming key opportunities to diagnose other hearing-related health impacts. But current regulations permit the sale of reading glasses without a prescription: While an opportunity to examine patients is lost, more good is achieved by allowing these sales. (Note: The OTC hearing aid bill passed since this conference).
- Reliance on smartphone technology for programming and use of OTC hearing aids and other hearing assistive devices to address hearing loss may present a challenge, as many older people are not comfortable using smartphones. This issue is likely to diminish over time, as consumers who are comfortable with smartphone technology age and begin to suffer hearing loss.

Session I: How Acoustics and the Built Environment of Public and Private Spaces Can Support Better Communication

Moderator: Brenda Battat, Former Executive Director, Hearing Loss Association of America

David deWilde, Stanford Center on Longevity Advisory Council

David deWilde noted that he and Katherine deWilde underwrote this conference because of their belief that hearing loss is a widespread problem that has become increasingly urgent as we achieve longer lives. They believe that the difficulties and the risks to cognitive abilities are still poorly understood and that people of all ages need a better understanding of the problems. They are eager to use the Center's ability to convene a national group of experts to establish priorities for effective action. Mr. de Wilde pointed out that, even with access to state-of-the-art technology, those with hearing loss still endure frustration and a sense of social isolation. He pointed out the poor acoustics in many public spaces, particularly restaurants, that disrupt even the best hearing devices. The deWildes particularly sought to bring together experts who understand the acoustics of the built environment with those whose focus is on the physiology of the human ear.

Charles Salter, Acoustical Engineer, President of Charles M. Salter and Associates, Inc.

Salter said his primary goal is to help hard-of-hearing people who cannot understand what is being said. Although acoustical standards have been known for at least 60 years, they are often excluded from design decisions. For example, if Stanford University planners had implemented existing standards for the conference room in which the conference was being held, audio operators would not have been needed.

When asked whether standards for classrooms are transferrable for other settings, Salter replied that they are, indeed, applicable. The space has to be quiet enough, has to account for reverberation, and there has to be an appropriate signal-to-noise ratio (15dB). He added that schools were moved to action by force: parents sued the government, claiming the poor hearing environment prevented their children from learning. Thus, planners, architects, and builders may not consider the acoustics of the built environment in the absence of the threat of a lawsuit.

Responding to a question about the financial impact of implementing good acoustics in a building project, Salter noted that putting acoustics into the design phase is a "trivial cost." By contrast, retrofitting is very expensive. In fact, for conference rooms and other large venues, a good acoustic design would pay for itself by eliminating the need to bring in audio engineers, special equipment, etc.

Poppy Crum, Chief Scientist, Dolby Laboratories and Consulting Professor, Stanford University

Crum began by describing the technological convergence between virtual reality (VR) and augmented reality (AR), which is highly applicable to hearing. For example, it's possible to think of a hearing aid as an AR device, incorporating data on noise, cognitive load, and environment in which communication is taking place. To promote this may require regulations that better facilitate use of data to improve hearing devices. The hope is to inspire improvement in consumer-level devices through performance standards, modification of existing devices, and assessing success.

With regard to the stigma often associated with wearing hearing aids (women believe they look less attractive; men believe they look less virile), the convergence of AR and hearing aids will likely be a boon to society. Like fashion eyewear, hearing aids may become a style choice.

Although there are existing standards regarding hearing devices, there is little consensus on which standards should be followed. Moreover, technology is changing so rapidly that it is difficult to develop general, lasting standards. Finally, unlike vision correction, hearing aids must be adapted to the physiological characteristics of each wearer's ears, complicating the acquisition process.

Susi Stadler, Principal at Stadler Architecture; Cofounder and Executive Director, At Home with Growing Older

Acoustic optimization too often comes as an afterthought to designers creating built environments such as offices, restaurants, and other venues where verbal communication takes place. Age-friendly design is important to the growing demographic of older adults, many of whom suffer from hearing loss. Particularly in social venues such as restaurants and bars, noise is conflated with vibrancy – thus proprietors may come to believe that a noisy environment, which is undesirable for communication, provides the draw for the “in” crowd.

Stadler said she believes that lack of acoustic intention is a discriminatory practice in public spaces. She believes builders should weigh not just the cost of acoustically beneficial materials, but the cost of retrofitting as well. Ideally, architects and builders should consider all sensory experiences, from minimizing glare to furniture arrangements that enhance face-to-face (which aids the hearing-impaired with communication, in many situations), to utilizing transparent doors through which people can observe activities in other spaces.

Open Discussion:

Important spaces to consider

- Elderly care facilities: The dining room is the main place to socialize, but because such rooms are often not acoustically treated, the residents cannot carry on a conversation. Acoustics need to be on a “certification checklist” for spaces for the aged population.
- Restaurateurs don't care about noise unless it affects their bottom line. Only then do they consider hiring an acoustical engineer to design a retrofit.
- In principle, restaurants could also be separated into quiet and noisy areas. A current lack of sensitivity is based on catering to younger people, who may express a preference for a livelier, often louder environment.

The example of Meyer Sound

John Meyer, co-founder of Meyer Sound, wanted to fix the restaurant environment. His quest was to create a lively, bustling restaurant, where the owners could control sound with an iPad. This would allow them to have, for example, a noisier bar, but more intimate settings in the dining room.

- Intelligent devices that work with the environment and deal with the intensity and complexity of the noise can be helpful tools in creating multi-faceted acoustic environments.
- Stanford’s Lathrop Room #282 allows a “small spaces” setting in a large physical environment.

Culture

Architectural acoustics has been taught in schools for 50 years, but it is not a driving force behind standard design. Moreover, architects who are perceived as over-emphasizing acoustics run the risk of alienating clients. Changing the culture would go a long way toward improving the hearing environment. Clients, owners and/or regulators can play a key role in evolving this change.

Opportunities to promote change

- Engage city planners reviewing the acoustics of government spaces and parks.
- Work with the building department so that hearing considerations become part of the building code.
- Examine the type of sound isolation required in California for multi-family housing projects. This could provide a model for regulating and promoting optimal acoustics.
- Include older-adult advocacy groups in designing and planning.
- Consider promoting acoustic design in the same way as green or LEED standards are.
- Promote understanding and a passion for acoustics that goes beyond ADA standards.
- Use the example provided by deaf people, who have no choice but to advocate for assistance with translation and interpretation.

Imagining Possibilities: The Meyer Sound Constellation System

Bob Smith, Director, Classroom Innovation, Stanford University

Pierre Germain, Constellation Design Manager, Meyer Sound

Tobi Szuts, Research Scientist, Meyer Sound

Room 282 in Stanford University's Lathrop Building is the first classroom at any university to feature the Meyer Sound Constellation System. The 3,000-square foot room contains 40 hanging microphones and 76 speakers²⁰ which can be controlled according to the acoustical needs of the class using the room. The Constellation system originated with Mark Poletti of Auckland, New Zealand, who developed a reverberation algorithm for use in controlling room acoustics electronically. Ultimately, the technology was acquired by Meyer Sound, which has developed and commercialized the system for use in public spaces.

Impact of the Constellation system at Lathrop:

- Instructors are able to address a class full of students without raising their voices.
- Instructors can move about the classroom freely and still be heard from all corners, even if they walk behind a wall or other visual barrier.
- Students can engage in small-group conversations simultaneously. Overlapping noise from other groups is reduced to an unobtrusive buzz.
- Environmental sound manipulations happen passively on the part of the students; i.e. they do not have to do anything to make it work.
- Classroom engagement is enhanced when the teacher does not need to shout and students do not need to remain silent.
- Hand-held microphones are not required; students can be heard speaking in their normal volume, which leads to more organic conversation.
- The task of lecturing is more natural and less physically demanding.

Barriers to implementation:

- Configuring a room with the technology is complex and expensive.
- The Constellation system at Lathrop cost \$350,000 (although expected economies of scale should bring the cost down substantially in the future).
- HVAC system air flow must be taken into account.
- Lighting still matters for making sense of hearing, even with the Constellation system in place
- Individuals with hearing aids may still have difficulty, particularly if the person speaking is out of their line of sight.

The presenters offered information on restaurants in the San Francisco Bay Area that feature the Meyer Sound Constellation system:

<https://www.dwell.com/article/sound-design-for-a-bustling-san-francisco-restaurant-8639eb6a>

The Future of “Hearability:” Where Could We Go From Here?

Moderator: Mark Cullen, Professor of Medicine, of Biomedical Data Science, of Health Research and Policy, Stanford University School of Medicine; Senior Fellow, Stanford Institute for Economic Policy Research (SIEPR)

Noting his past experience diagnosing the causes of hearing loss, especially those occupationally related, Cullen discussed the relationships between hearing loss and injury, and hearing loss and chronic disease. Mitigating this major societal epidemic is a tremendous challenge.

Robert Jackler, Professor in Otorhinolaryngology and Professor, by courtesy, of Neurosurgery and of Surgery, Stanford University School of Medicine

According to Jackler, the three key issues in addressing hearing loss are stigma, cost, and cure.

Stigma

Although hearing is a fundamental function of a healthy life, our culture continues to characterize hearing-aid wearers as “old” and “dumb.” This negative characterization can induce some people to consider risky operations, solely to avoid having to wear a device in the ear. At the same time, new innovations like Google Glass and Bluetooth wireless technology are seen as hip and revolutionary status symbols of a new era. More and more, our devices respond to speech as well, so the human voice and ear are central to future technological developments. The advent of in-ear devices that everyone wears -- for translating languages, listening to music, or recording biometric information, for example -- could normalize the use of hearing aids, advancing the opportunity to transform visible technology in the ear from stigma to status symbol.

Cost

The hearing aid economy is ripe for disruption. Prices are too high, particularly since hearing loss most affects older people, who are likely to be retired and sensitive to issues of cost. Many costs could be reduced through technology, such as testing and adjustments, which could be largely automated.

Cure

Only a few specific hearing- and ear-related issues can be addressed surgically: holes in the eardrum and “nerve deafness” of the cochlea are rare. Hearing loss is usually caused by the loss of hair cells, which are limited in number and do not regenerate. At present there are no workable methods for operating in the ear, but scientific advances in that area hold great promise.

In response to a question about the balance between technology and physiological solutions, Jackler replied that a resilient biological fix would be the ideal, since even the most advanced technology will be

limited by distortions that develop in the ear. “No matter how advanced we make the telephone, if the wire is damaged it won’t work.” The ear contains the finest acoustical instruments that technology cannot match. As such, there should be a complementary relationship between developing wearables and exploring biological solutions. One example is the photonic hearing aid, which utilizes the light spectrum rather than radio frequency in order to enhance frequency response. Additionally, although a biological approach will be a costly and time-consuming endeavor, it may ultimately prove to be the most cost-effective solution over time.

Gretchen Addi, Consultant and Designer-in-Residence, AGING2.0

Technology is racing forward, said Addi, yet culturally we are lagging behind. How can we start to shift and change our behavior and culture to bridge the gap?

As noted previously, stigma and ageism are not easy to overcome. Moving from talking about “hearing aids” to talking about “wearables” could affect people’s willingness to seek help. Framing interventions as “assistive technology” may also help reduce societal stigma, especially since no one has perfect hearing, no matter one’s age.

Addi noted that her husband found out he was at the low end of normal range for hearing in his age group, and as a result began wearing ear plugs in the music studio. In this case, rather than considering hearing loss as a flaw, it was about how to create the best possible experience. This is done by a shift to modeling the problem from a human-centered perspective versus aging. Websites like Mimi (<https://mimi.io/en/hearing-test/>), where a person can test their hearing and figure out how to fine tune it, are ways forward.

“Happy accidents”

The potential for driverless cars is an exciting new development. But we aren’t creating them with the aim to help older adults; it’s a happy accident that they will. Similarly, there is great opportunity for finding more happy accidents in things like virtual reality (VR) and gaming technology.

Convergence

While expertise is being developed in many areas related to hearing, much of it has occurred in silos (e.g. technology, medicine, etc.). Interdisciplinary approaches tend to lead to better solutions.

Choices

How can we offer more choice to consumers in the public square, for example the choice of a “lively” table or “quiet” table at a restaurant?

An IDEO design team created a video depicting friends gathering at a pub. Upon entering, they see a sign in the window, reading “Hearware.” So they request the “Hearware” from the hostess, who provides each of them with a pair of earbuds. As they put the earbuds in, the sound in the video changes, and the friends hear only each other. When they are ready to leave, they leave the earbuds on the table and head out. Offering a “hearware” choice could accommodate individual hearing challenges without forfeiting the “vibrancy” of a new hot spot, as exhibited by high noise levels.

Amanda French, Innovation Fellow '16-17, Stanford University, Byers Center for Biodesign

Stanford's Biodesign Innovation Program, initiated by Cardiologist Paul Yock 17 years ago, has assembled a wide range of people from different backgrounds and disciplines who work together to develop solutions that address unmet needs in healthcare. Though intentionally interdisciplinary, the program largely attracts engineers and doctors. Biodesign uses a needs-based, user-centered, and process-driven approach to drive product design.

Framing provides an important lens on the work. For example, online resources provide only the limited perspective of a particular hearing aid company. A better approach might be to shadow hearing-impaired individuals to identify critical issues – that people misplace their hearing aids when they remove them from their ears, or that people leave restaurants early out of frustration with their inability to hear conversations.

Biodesign fellows learn a 'filtered approach,' which has several steps, including:

- Identify as many problems as possible (perhaps "200") within a chosen scope, e.g. aging
- Characterize the needs in terms of problem, population, and outcome
- Filter the needs to identify those that could have the largest impact (in terms of number of patients affected, impact on quality of life, financial burden, etc.)
- Continue filtering based on treatment landscape, clinical pathway, regulatory pathway, and stakeholder alignment
- Narrow the scope to, for example, to 16 issues, and brainstorm potential solutions.
- Research technical feasibility, freedom to operate, and patentability of brainstormed solutions to narrow the needs down to a final list of 2-4
- Create an implementation plan for the final needs (investigate business model, commercialization strategy, etc.) and select the final need to pursue
- Find a manageable course of action that ensures the path taken will have long-term viability

"Framing" provides a means for generating solutions. For example, if the problem is that voices are too low to hear, the solution might be hearing aids that amplify noise. But if the problem is declining social connection, then solutions might include modification of the built environment of restaurants, bars, and coffee shops, as well as amplification of voices. Direct observation of the problems the hearing-impaired face leads to a more robust array of solutions to superficial, as well as associated, real-life challenges.

David Eagleman, Neuroscientist, Department of Psychiatry and Behavioral Sciences, Stanford University School of Medicine

The brain is a computing device, Eagleman said. We feed information into it, and it figures out what to do.

To address hearing loss, one method is to explore sensory substitution. How can you deliver information via an unexpected channel in a way that the brain can decipher it? Eagleman's lab developed a smartphone-

connected vest to be worn under clothing which translates sound into a pattern of vibrations -- which is exactly how the inner ear works. As the vest detects sound from the environment, it is experienced as patterns of vibration across the wearer's torso. With enough practice, wearers can learn to understand what people are saying around them. While this tactile approach is effective, however, the older a person is, the longer it takes him or her to learn to interpret the signals.

Current testing explores the device's utility for all ages, even babies. The lab has also fabricated a wristband that addresses high-frequency hearing loss which can distinguish between phonemes that are often difficult to differentiate. The products will be available commercially next year at Neosensory (<https://neosensory.com/>). Since they are worn under the clothes or on the wrist, they are not visible and therefore free from the stigma of other hearing devices. The wristband model will also benefit from the popularity of other wearables that are commonly worn on the wrist. The company aims to keep device costs reasonable, and is also exploring a model whereby for every device sold the company donates a device to someone who could not otherwise afford it.

Session II: Integration and Inter-operability of Technology and Services

Moderator: Zina Jawadi, Undergraduate Student, Stanford University, Department of Biology

Judy R. Dubno, Professor, Director of the Hearing Research Program, Medical University of South Carolina

Hearing-related healthcare consists of technology, devices, and services that address individual needs. In the case of treating hearing loss, no one size fits all.

An assessment to determine the best combination of technology and services includes:

- empowering individuals to make their own choices;
- asking questions about the individual's living situation, as well as comfort with learning new technology
- including family and/or primary communication partners in the assessment. Hearing loss doesn't just affect the individual, it affects the whole family.

Accessing hearing health care is complex. Typically, the journey begins when an individual realizes that he or she is experiencing hearing loss and associated negative effects. Unfortunately, the path to helpful alternatives can be complicated and confusing.

Social support is critical to success in addressing hearing loss. Just as a surgery patient is placed on a post-operative physical therapy regimen, those with hearing loss would benefit from similar programs – technology assistance, professional counseling, peer support groups, auditory training, and education, for example.

The two main obstacles to adoption of more widespread use of hearing devices are the lack of integration with other technology, and the cost. Over-the-counter devices hold the potential to reach more people due to their lower cost, but still need to include warnings that lead consumers to seek further help under certain conditions.

Thibault Duchemin, Chief Executive Officer and Founder, Ava

Hearing is an integral component of social connection – one of the three critical factors in aging well as we approach centennial lives. Duchemin, whose first language was American Sign Language (ASL) recommends that those experiencing hearing loss must talk about the social impact of it with friends, family, and coworkers.

In our culture generally, addressing hearing loss is seen as the sole responsibility of the person who cannot hear. By contrast, a family that relies on ASL to support the needs of a hearing-impaired member share responsibility for including the entire group in communication management. Rapid advancements in integrating speech and captioning offer great promise. For example, Ava (<https://www.ava.me/>) is a smartphone app that facilitates group conversations, typing what is spoken so the hearing-impaired can read the conversation in real time. The app allowed an 87-year-old man dining out with his family to read the dessert offerings as the waiter recited them aloud, facilitating a sense of renewed connection to his loved ones.

Anyone with a smartphone can use the Ava app. Importantly, hearing accommodation can be helpful for everyone, including the hearing community – from a student attending a lecture to a tourist visiting a new town, or those who want to watch TV while their partners sleep.

The Ava app functions only when those in the group opt in to use it. No data are collected or monitored for conversational content.

Daniel Shen, Founder, Chief Clinical and Science Officer, Eargo

Eargo is a hearing-focused company comprising a product, a channel, and a service. Noting the dismal adoption rate of products and services related to hearing loss, he said most people suffer with declining hearing for nearly a decade before seeking help and only 20 percent of those who need devices actually get them: Once devices are obtained, they often then tend to sit in a drawer.

The key barriers to use of hearing devices are

- Stigma: To make their hearing aid invisible, Eargo created a very small and unnoticeable device.
- Comfort: The physician-designed soft silicone fitting adapts to each individual’s ear canal.
- Ease of use: By incorporating a long-lasting, rechargeable battery and eliminating buttons and dials, the product circumvents the need for constant, cumbersome adjustments.
- Price: Eargo retails at less than half of industry average.
- Access: Customers are able to consult with hearing professionals remotely.

Key Eargo goals include creating a simple and compelling experience for the user, distribution of the devices to those who would benefit from them, adoption closer to the onset of hearing loss, and improved satisfaction with the device. So far, Eargo has been attracting a large number of first time users and also attracting users that are significantly younger than the average hearing aid user.

Open Discussion

Initial Device Configuration

There are two existing models for providing a bridge between the hearing aid and the person who needs services: “tele-audiology” (utilizing web-based video communication), and clinic-based services.

- Satisfaction is higher when people receive services from an audiologist. Doctors at Stanford are trying to move away from purely technology-based service delivery and instead focus more on strengthening social connection and rehabilitation.
- In a randomized clinical trial comparing video to face-to-face instruction with identical devices, user satisfaction was virtually identical.
- A certain segment of population has a higher need for assistance, but most patients are independent enough to find help on their own through videos, etc. Complex hearing issues are more likely to require the services of an audiologist, whereas over-the-counter devices are satisfactory for simpler cases.

Hearing Healthcare Delivery

A chief goal for assistance with hearing loss should be comprehensive delivery, versus the current piecemeal approach. This should begin through partnering with insurance plans, including HMO models, which may be well positioned to provide services under one umbrella. For example, Hear USA has a joint venture with Kaiser Permanente to provide coverage for seven million patients through their Head and Neck departments. Kaiser provides testing and support, as well as referrals to dispensers of hearing aids. Third parties such as Medicare and Medicaid pay for 75 percent of this business.

In some localities, healthcare organizations are training volunteer community healthcare workers to address basic hearing needs and provide direct services. These lay providers know their local communities and are able to provide consumers with referrals to audiology clinics. A similar system is needed to facilitate initial screening and set-up of over-the-counter devices, which can then be delivered directly to the person in need.

Issues to be Addressed

- Service providers and others should examine whether the services they offer could be better accessed and utilized through advances in technology.
- Proprietary hearing devices hinder broader adoption and integration. Even though there are a wide variety of hearing devices at a wide range of price points, most are based on the same core technology.
- Standardization would provide consumers with more control over how their devices interact with their environment.
- Improving accessibility and the range of choices could enable individuals to get help sooner.
- Only 20 percent of people who need hearing assistance take advantage of products and services, and those who do wait too long. This leads to negative health outcomes, including falls and dementia.
- Hearing devices are typically sold to individuals as a bundle, with the hearing assistance device costing about a third of the rate charged. The rest of the money goes to audiology services, insurance companies, and marketing expenses to improve utilization. With increased utilization and early adoption, costs would be reduced substantially as the need for extensive marketing would not be as great.
- Over-the-counter solutions may prove challenging to implement, particularly for individuals who need more technological support or have more specialized hearing needs.

Captioning

- For lip-reading, pairing audio and visual cues is critical, but poorly executed. A time lag greater than one second impacts a person's ability to understand a conversation; developing awareness around the issue should lead to better design solutions. Lip-reading also takes years of training, holds a high potential for miscommunication, and is affected by extraneous visual cues.
- To build hearing infrastructure, large organizations or groups, especially those in the entertainment industry, play a critical role. Even though closed-captioning for television has become more and more available, it is not always implemented effectively (for example, using white text on a complex background).
- Other technologies might prove superior – for example, streaming dialogue directly to the ear and allowing the user to establish personal control settings.

Noisy Environments

Two key technology issues for optimizing hearing in a noisy environment are projecting the dialogue, and separating an individual voice from the background din. Ideally, broadcasters and sound technicians would transmit audio programming in ways that effectively interface with hearing devices. Additionally, devices need to be “smart” enough to mute ambient noise in favor of vocal clarity.

Other Key Technology Questions

- Developing hearing aids that sense the external environment and adjust to it requires moving away from fixed digital signal processing (DSP) algorithms and chip sets toward “smart,” machine-learning devices.
- Improving the signal-to-noise ratio ultimately depends on the distance between the source and the microphone, so moving microphones closer to the individual is key.
- Given the shrinking size of devices, manufacturers are reaching a limit to what can be achieved with batteries (which may lead to more technologies like Ava that mediate between the device and the individual).
- There is great opportunity to develop new products and technologies to enhance and improve hearing for those suffering hearing loss. The real need is to provide a comprehensive, integrated approach to improving hearing.
- Personalized ways of consuming content might evolve to assist the hearing impaired. For example, a successful version of Google glass could bring a visual captioning element to auditory intake.

Session III: How Policies, Research, and Education Can Influence Change

Moderator: Jack Rowe, Professor, Department of Health Policy and Management, Columbia University Mailman School of Public Health

Policy Considerations

- The new commissioner of the Food and Drug Administration favors deregulation, which means he will likely ease regulation of hearing aids, but make no effort to increase consumer protection.
- Municipalities across the country have different rules about hearing accessibility in schools, courthouses, etc.
- Health insurance coverage varies state-by-state. In many cases, hearing aids are not covered.

Payers

Most people in the United States procure health insurance through their employers. As a result, it would seem that activist employers have the potential to drive the insurance industry to offer policies that cover hearing devices.

Some large employers are role models for offering hearing-related health coverage. For example, the federal government, Boeing, AT&T, the World Bank, and the motion picture industry generally offer strong hearing-related benefits. Medicare covers some medically-related diagnostic procedures, but doesn't cover hearing exams, hearing aids, or fittings for hearing aids. Notably, some large employers whose workplace conditions contribute to hearing loss (Chrysler, for example) do not offer widespread hearing assistance coverage.

Companies that provide insurance coverage of hearing devices are better able to attract and retain work force talent. Broadly communicating this critical message will result in better insurance coverage and more qualified work force retention.

Advocacy

In order to increase the availability and usage of hearing devices, advocates such as the American Association of Retired Persons (AARP) must engage in education and promotion efforts. Currently, the chief method for enhancing acoustic accommodation in public spaces is through the legal system, where people with disabilities are the driving force. A public information campaign may encourage regulators to ensure that public spaces are designed in acoustically-sensitive ways, taking into account the hearing-impaired population.

Marketplace Considerations

Since hearing aid device prices tend to be high, insurance premiums to cover them will also be necessarily high, despite the fact that when hearing loss is addressed adequately, there may be net long-term savings in healthcare expenditures. Business leaders must consider the cost of insurance plans that suit current employees, as well as company retirees who continue to be insured. Admittedly, fewer and fewer companies are offering health insurance coverage to their retirees, which may be a disincentive for insurance plans that provide coverage of hearing aids.

Financial Considerations

Reimbursement models for hearing tests, services, and devices are inconsistently applied and often confusing. Most often, insurers who cover hearing-related issues provide a fixed dollar amount rather than reimbursement of actual fees. It could well be that unbundling testing, services, and devices could lead to the development of a better model. For now, the perceived lack of epidemiological data concerning hearing loss, combined with the wide disparity in whether devices are covered or not have created confusion, leaving many to opt out of seeking assistance at all.

Also recommended: more collaboration among physicians, audiologists, technology producers, and others to develop recommendations for best practices, leading to lower costs and higher accountability.

Session IV: Setting the Research Agenda

Moderator: Laura Carstensen, Professor of Psychology, Stanford University; Director, Stanford Center on Longevity

Gerald Popelka, Consulting Professor of Otolaryngology/Head and Neck Surgery, former Chief of Audiology, Stanford University School of Medicine

Judy Dubno, Professor, Director of the Hearing Research Program, Medical University of South Carolina

David DeWilde, Stanford Center on Longevity Advisory Council

Carstensen briefly summarized the day's discussion noting that the group consensus was that change is urgently needed. With new technologies, such as Ava and Eargo, new opportunities are emerging. The question now is how to accelerate the pace of change, and what the conference attendees can propose that would improve the situation for a long-lived society.

Below is a summary of the group consensus about next steps:

Goals and Outcomes

A chief outcome for driving change is the development of a consensus paper that sketches out an implementation plan of action, in collaboration with Stanford University's School of Medicine.

This will be most effective if we can prioritize needs and be as specific as possible, rather than simply making broad recommendations. One path forward is to build on the National Academy list of recommendations on hearing with more specificity and actionable ideas, categorizing recommendations by type: regulatory standards, policy, and best practices, for example. A small, cross-disciplinary study could contribute to existing data.

At Stanford, appointing a task force to provide the Provost with specific recommendations for retrofitting campus facilities for hearing accessibility should include objective estimates of financial loss due to hearing deficiency, as well as potential savings of addressing hearing challenges. Presenting a cost-benefit analysis could enhance conditions as well as financial savings.

Environment at Stanford

How many of Stanford's many construction projects take acoustics and accessibility into account? Many campus buildings, such as Memorial Auditorium, would benefit from acoustical improvements.

Stanford's Standards and Compliance Office, which makes sure new structures are ADA compliant, should be involved in addressing hearing concerns as well. Yet the office is under-resourced, with just two in staff who are not trained in acoustic design. Including a Standards and Compliance officer in our task force would help advance the work in this area.

Additionally, Stanford has no central authority for focusing on disability, despite having representatives for other minority groups and interests. By advancing an understanding that hearing loss represents an underserved population, we can begin to convince others of the need for hearing accessibility.

General Factors Regarding the Built Environment

- The Milken Group produces an annual list of age-friendly cities. There is also a rating for the most accessible cities.
- Highlight the connection between age and hearing loss.
- Room acoustics could be included in ADA or other regulations. Require builders to take room acoustics into account in order to receive certificates of occupancy or dwelling.
- In California, the Division of the State Architect sets the building code, which is revised every three years. A public push to include acoustic design in the building code – perhaps as a disability issue – could provide vast improvements for the hearing impaired.
- Support a restaurant ratings system based on ambient noise. For example, *The San Francisco Chronicle* has “bells” and “bombs” for noise ratings. Including these ratings in more publications could be very useful.

Regarding the Effectiveness of Treatment by Doctors

- A common entry point for those seeking treatment for hearing loss is to visit a primary care physician, who generally is not trained in hearing loss. If medical training programs educated students in initial hearing screening, more people could be served more quickly, and at lower cost. Additionally, encouraging more interdisciplinary interaction between primary care physicians and hearing specialists would increase understanding and guide more patients into treatment. Stanford Medical School could be a testbed for this approach.
- One method of promoting treatment of hearing loss is to educate the public about healthy hearing metrics. Just as people can check their own blood pressure and evaluate whether to see a doctor, hearing metrics could be publicized and hearing tests made easily accessible.
- Although hearing loss is a natural part of aging, failure to treat it leaves sufferers at risk of negative psycho-social and other health aspects that stem from it.

Hearing Aids

- People with hearing loss do not have sufficient information to compare different hearing aids and technologies.
- Hearing aid wearers often have insufficient awareness of their own devices. For example, most people do not know if their hearing aid has a tele-coil.
- Information about hearing aid features can be hard to find; sometimes audiologists do not even know the most useful features for an individual.
- Creating “hearables,” or devices that enhance hearing that are as commonly utilized as “wearables” are now, could reduce the stigma traditionally associated with hearing aids.

Regulatory Reform

- Influencing FDA regulations regarding hearing aids is desirable, but the process is extremely slow.
- Vested interests in the hearing field may prevent meaningful reform, unless advocacy groups like those for the Americans with Disabilities Act (ADA) become involved.

Awareness Campaign

- Public awareness programs have the power to alter consumer attitudes and promote lasting change, as has been demonstrated in the case of smoking cessation, breast cancer prevention, and drinking and driving, for example. There is a need for a similar marketing campaign aimed at shifting attitudes and behavior surrounding hearing loss.

Conclusions

From the conference, several key topics of interest emerged:

- Hearing loss not only affects the impaired, it affects all those who interact with sufferers. Thus, the responsibility for “fixing” the problem lies not only with the person with hearing loss, but with policymakers, architects designing built environments, and the general community as well.
- Hearing loss is correlated with numerous other illnesses both physical, psychological, and cognitive, and has a deleterious effect on mortality. Hearing loss is a public health issue that must be treated as such.
- Recognizing and understanding the four main barriers to hearing aid use is essential to shifting awareness. The barriers are affordability, access to services and technology, technology design and utility, and awareness and understanding the ramifications of failure to treat hearing impairment.
- Technology has come a long way, yet the different technologies do not link easily with one another and, more importantly, do not yet link with services. Creating bridges between technologies and services would advance use and adoption of hearing improvement methods.

Conference attendees discussed the need for progress in these areas, and highlighted the need for further conversation and research that supports communication among those with and without hearing loss.

Next Steps

The Stanford Center on Longevity is in discussions with several researchers and industry leaders about next steps.

- A Stanford Task Force to support “hearability” on campus submitted a proposal to the President’s Long-Term Planning effort to have Stanford serve as a pilot “hearable university.” Such an effort would include:
 - Creating a screening and consulting program for Stanford employees to raise awareness of the effects of age-related hearing loss.
 - Adding age-related hearing loss to the School of Medicine curriculum.
 - Conducting a study of the efficacy of our interventional plan/program.
- Conducting research about the effectiveness of various hearing devices to improve communication and social engagement across a variety of settings for those with hearing loss.

Resources

Journals

American Journal of Audiology, 25(1)

Ear and Hearing, 30(3)

The Gerontologist, 40(3)

The Gerontologist, 19(1)

The Nurse Practitioner, 21(9)

Journal of Aging and Health, 14(1)

Journal of the American Geriatrics Society, 37(2)

Journal of the American Geriatrics Society, 62(5)

Journal of Gerontology, 36(3)

Journal of the American Medical Association, 173(4)

Seminars in Hearing (Vol. 25, No. 02)

Social Psychiatry and Psychiatric Epidemiology, 42(2)

Web resources

http://www.hearingloss.org/sites/default/files/docs/HearingLoss_Facts_Statistics.pdf

<http://www.amplifonusa.com/hearing-loss>

Endnotes

- ¹ http://www.hearingloss.org/sites/default/files/docs/HearingLoss_Facts_Statistics.pdf
- ² <http://www.amplifonusa.com/hearing-loss>
- ³ Lethbridge-Cejku, M., Schiller, J. S., and Bernadel, L. (2004). Summary health statistics for U.S. adults: national health interview survey, 2002. *Vital Health Stat.* 10, 1–151.
- ⁴ http://www.hearingloss.org/sites/default/files/docs/HearingLoss_Facts_Statistics.pdf
- ⁵ http://www.hearingloss.org/sites/default/files/docs/HearingLoss_Facts_Statistics.pdf
- ⁶ Bess, F. H., Lichtenstein, M. J., Logan, S. A., Burger, M. C., & Nelson, E. (1989). Hearing impairment as a determinant of function in the elderly. *Journal of the American Geriatrics Society*, 37(2), 123-128.
- ⁷ Lin, F. R., Yaffe, K., Xia, J., Xue, Q. L., Harris, T. B., Purchase-Helzner, E., ... & Health ABC Study Group. (2013). Hearing loss and cognitive decline in older adults. *JAMA internal medicine*, 173(4), 293-299.
- ⁸ Chen, D. S., Genther, D. J., Betz, J., & Lin, F. R. (2014). Association between hearing impairment and self-reported difficulty in physical functioning. *Journal of the American Geriatrics Society*, 62(5), 850-856.
- ⁹ Hawthorne, G. (2008). Perceived social isolation in a community sample: its prevalence and correlates with aspects of peoples' lives. *Social psychiatry and psychiatric epidemiology*, 43(2), 140-150.
- ¹⁰ Kramer, S. E., Kapteyn, T. S., Kuik, D. J., & Deeg, D. J. (2002). The association of hearing impairment and chronic diseases with psychosocial health status in older age. *Journal of Aging and Health*, 14(1), 122-137.
- ¹¹ Strawbridge, W. J., Wallhagen, M. I., Shema, S. J., & Kaplan, G. A. (2000). Negative consequences of hearing impairment in Old Age a longitudinal analysis. *The Gerontologist*, 40(3), 320-326.
- ¹² Wallhagen, M. I., Strawbridge, W. J., & Kaplan, G. A. (1996). 6-year impact of hearing impairment on psychosocial and physiologic functioning. *The Nurse Practitioner*, 21(9), 11.
- ¹³ Berg, S., Mellström, D., Persson, G., & Svanborg, A. (1981). Loneliness in the Swedish aged. *Journal of Gerontology*, 36(3), 342-349.
- ¹⁴ Kivett, V. R. (1979). Discriminators of loneliness among the rural elderly: Implications for intervention. *The Gerontologist*, 19(1), 108-115.
- ¹⁵ Nachtegaal, J., Smit, J. H., Smits, C. A. S., Bezemer, P. D., van Beek, J. H., Festen, J. M., & Kramer, S. E. (2009). The association between hearing status and psychosocial health before the age of 70 years: results from an internet-based national survey on hearing. *Ear and hearing*, 30(3), 302-312.
- ¹⁶ Weinstein, B. E., Sirow, L. W., & Moser, S. (2016). Relating Hearing Aid Use to Social and Emotional Loneliness in Older Adults. *American journal of audiology*, 25(1), 54-61.
- ¹⁷ Boothroyd, A. (2004, May). Room acoustics and speech perception. In *Seminars in Hearing* (Vol. 25, No. 02, pp. 155-166). Copyright© 2004 by Thieme Medical Publishers, Inc., 333 Seventh Avenue, New York, NY 10001, USA.
- ¹⁸ http://www.hearingloss.org/sites/default/files/docs/HearingLoss_Facts_Statistics.pdf
- ¹⁹ http://www.hearingloss.org/sites/default/files/docs/HearingLoss_Facts_Statistics.pdf
- ²⁰ Humes, Larry E., Sara E. Rogers, Tera M. Quigley, Anna K. Main, Dana L. Kinney, and Christine Herring. "The Effects of Service-Delivery Model and Purchase Price on Hearing-Aid Outcomes in Older Adults: A Randomized Double-Blind Placebo-Controlled Clinical Trial." *American Journal of Audiology*, 2017, 1. doi:10.1044/2017_aja-16-0111.